Faculty of Applied Science and Engineering

Proposed Engineering Science Major[1] in Engineering Mathematics, Statistics and Finance

Introduction:

In April 2008, a working group was struck by the Division of Engineering Science to examine the idea of developing a Major in Engineering Science in the field of Financial Engineering. This idea grew out of a grass roots interest in hosting such a Major from the Department of Mechanical and Industrial Engineering (MIE) and was encouraged by the Division of Engineering Science when the decision was made by MIE to cancel the Manufacturing Systems Major.

The working group had the following membership:

Professor Roy Kwon (MIE)
Professor Daniel Frances (MIE)
Professor Yuri Lawryshyn (Chemical Eng. & Applied Chemistry)
Professor Sebastian Jaimungal (Statistics)
Professor Alan White (Rotman)
Mr. Glynn Williams (alumnus)
Dr. Murray Metcalfe (alumnus)
Ms Angela Tran (graduate student)
Ms Lisa Romkey (EngSci)
Professor Will Cluett (EngSci)

A proposal for a Major with the proposed name "Engineering Mathematics, Statistics and Finance" was developed by the working group and is outlined in this document. The choice of name was made because it is an engineering program built around advanced courses in mathematics and statistics with finance as an integral part of the program.

The working group felt that this would be an excellent fit for Engineering Science because (1) this is a critical area of importance in the modern world where having a quantitative/engineering background is a great advantage, (2) many Engineering Science students have expressed interested in such a Major, and (3) the background required for successful participation in the field is exactly the type of background that Engineering Science provides.

This area is highly relevant to Engineering Science because it is engineering in the most modern yet traditional sense. By now there is a wide body of financial theory in place to explain the dynamics of financial instruments and markets that impact just about everyone in the world. This characterization is highly rigorous, mathematical, quantitative, and statistical, not unlike mathematical descriptions of the physical phenomena that underpin the more traditional Engineering Science Majors.

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[1] As approved by the Committee on Academic Policy and Programs, Options in Engineering Science are referred to as Majors on student transcripts. However, the word Option continues to be used to refer to the various choices of areas of specialization Engineering Science students have available to them prior to entering Year 3 and 4.

The essence of design in this field is based on practical constructs just like the design of a bridge would be for civil engineers except that the underpinning is mathematical financial theory. The designs in this field are more abstract than a bridge design but every bit as practical, e.g. a firm can engage in a contract design that minimizes risks, or the design of a portfolio of stocks to ensure a high quality of living for people participating in pension plans. The promise of the field is in the design of better financial arrangements for society.

A number of leading engineering schools around the world have already recognized that Financial Engineering fits within engineering (see below for examples at Princeton, Columbia, Stanford). U of T is a leading institution world-wide and the Engineering Science program is one of the most analytically demanding undergraduate programs at the University. Therefore, these students are well matched for the demanding rigor of Financial Engineering and will be well prepared to enter both the financial industry as well as tier 1 North American graduate school programs in related fields.

Princeton:
http://orfe.princeton.edu/
Columbia:
http://www.ieor.columbia.edu/pages/undergraduate/financial_eng/index.html
Stanford:
http://www.stanford.edu/dept/MSandE/

Learning Outcomes:

The Engineering Science Major in Engineering Mathematics, Statistics and Finance aligns with the Engineering Science program's degree level expectations. In particular, the Major will result in graduates that have:

- An understanding of financial market/instruments in terms of their role in society at large (capital markets, financial institutions, corporate finance)
- An understanding of the mathematical/computational/computing aspects of modern markets/instruments (stochastic calculus, optimization theory, statistics and financial econometrics, trading systems, programming, numerical computation)
- Explored some of the important problems in modern finance, including (a) pricing of contracts and (b) construction of financial portfolios
- Tackled financial engineering problems as they may occur in whatever possible variety
- Developed a quantitative background that would be sufficient preparation for graduate school in finance, operations research, applied mathematics, etc.

Recommended Themes:

The proposed curriculum for the Engineering Science Major in Engineering Mathematics, Statistics and Finance has been designed to give graduates background in the following three thematic areas:

Theme #1: Mathematics/Statistics
-Real Analysis
-Probability
-Stochastic Processes
-Time Series, Statistical Computation & Financial Econometrics

Theme #2: Finance/Financial Engineering
-Omnibus course in micro, macro, corporate finance and accounting
-Option Pricing
-Portfolio Optimization
-Financial Engineering
-Real Options

Theme #3: Computation
-PDE's and Numerical Methods
-Optimization
-Monte Carlos Methods
-Time Series & Statistical Computation

Proposed Curriculum:

3F Engineering Economic Analysis & Decision Making (CHE374) Methods of Data Analysis (STA302) Probability (STA347) Financial Engineering (MIE375)Partial Differential Equations (APM384)Option Seminar (ESC301)	3S Engineering Finance and Economics (CHE375) Intro to Real Analysis (MAT337) OR Real Analysis I (MAT357) Financial Principles for Actuarial Science (ACT370) Mathematical Programming (MIE376) Financial Optimization Models (MIE377)
4F Thesis HSS/CS elective Stochastic Methods (ACT460) EMS&F Elective #1 EMS&F Elective #2	4S Thesis HSS/CS elective Capstone Design (MIE479) EMS&F Elective #3 EMS&F Elective #4

New Course Descriptions:

MIE375: Financial Engineering

This course provides a background in the fundamental areas in financial engineering including relevant concepts from financial economics. Major topics include interest rate theory, fixed income securities, bond portfolio construction term structure of interest rates, mean-variance optimization theory, the Capital Asset Pricing Model (CAPM), arbitrage pricing theory (APT), forwards and futures, and introduction to option pricing and structured finance.

MIE376: Mathematical Programming

This course deals with the formulation of optimization models for the design and operation of systems that produce goods and services, and the solution of such problems with mathematical programming methods, including linear programming: the simplex method, sensitivity analysis, duality, the revised simplex, column generation, Dantzig-Wolfe decomposition and linear programming with recourse; minimum cost network flows; dynamic programming; integer programming; non-linear programming models.

MIE377: Financial Optimization Models

This course deals with the formulation of optimization models for the design and selection of an optimal investment portfolio. Topics include Risk Management, Mean Variance Analysis, Models for Fixed Income, Scenario Optimization, Dynamic Portfolio Optimization with Stochastic Programming, Index Funds, Designing Financial Products, and Scenario Generation. These concepts are also applied to International Asset Allocation, Corporate Bond Portfolios and Insurance Policies with Guarantees.

CHE375: Engineering Finance and Economics

This course consists of three modules: 1) managerial accounting, 2) corporate finance and 3) macro economics. The first module, managerial accounting, will consist of an introduction to financial statements and double entry recordkeeping, then delve deeper into aspects of revenue, expenses, assets, debt and equity. The second module, corporate finance, will introduce the concept of risk and return, and the Capital Asset Pricing Model, and then delve deeper into capital budgeting, corporate financing, financial statement analysis and financial valuation. The third model, macro economics, will introduce global aspects of business, including economic, political, societal and technological, then discuss factors such as GDP, inflation, unemployment, interest rates, foreign exchange rates, fiscal debt/surplus and balance of payments, and their impact on the financials of a given country.

Ideas for a Capstone Design Course MIE479: Engineering Mathematics, Statistics and Finance Capstone Design

The course would involve group projects where, given the field, the team would build a tool, likely a computer based mathematical modeling system.

1. The project should solve a real problem, and not be a theoretical derivation. Testing in the real world, perhaps with industry involvement, would be helpful in that regard. In particular the team might be required to explain to those who are not financial engineers themselves the purpose of the project and the approach as it evolves, to keep it tied to real world.

2. The project should be in a domain that is clearly technology/engineering related and driven. This way the project will tie to the broader engineering discipline.

3. To pull this into the real world further, there might there be a component of the modeling system that is real time, perhaps deriving data from some type of sensors or signaling mechanism.

4. The capstone project model might involve optimizing against an objective (i.e. goal) function that includes factors other than economic/monetary. This will likely make the project quite different from most of the Major course work and will be a "mind expander" for the students. It might include environmental and social factors - so called triple bottom line analysis - that would need to be factored in. There could already be work done in this field in the case of carbon markets and carbon credits. This type of multi-variable approach could become a specific research theme that faculty members might get involved in.

Engineering Mathematics, Statistics and Finance Major: Fourth-Year Electives

In Year 4 of the proposed curriculum, students select 4-5 EMS&F electives, depending on whether they do a half-year or full-year thesis, from the list of courses below. Students are required to take at least two from Group A and at least two from one of the domains in Group B. In addition, students must select their electives such that they meet accreditation requirements. These courses are subject to change and will be finalized for the 20111-2012 Faculty Calendar, the year in which the 4th Year of this Major will be first offered.

Group A: Methodologies and Tools Courses

AER336	Scientific Computing
APM466	Mathematical Theory of Finance
CHE507	Data-based Modelling for Prediction and Control
ECE358	Foundations of Computing
MIE360	Systems Modelling and Simulation
MIE365	Operations Research II
MIE367	Cases in Operations Research
MIE457	Knowledge Modelling and Management
MIE562	Scheduling
MIE566	Decision Analysis
RSM412	Financial Trading Strategies
RSM430	Fixed Income Securities
RSM432	Risk Management for Financial Managers
STA410	Statistical Computation
STA447	Stochastic Processes

Group B: Domain Courses

Aerospace

AER301	Dynamics
AER307	Aerodynamics
AER373	Mechanics of Solids and Structures

Biomedical

BME340	Biomedical Engineering Instrumentation and Technology
BME350	Physiological Control Systems
BME395	Cellular and Molecular Bioengineering I

Electrical and Computer

ECE349	Introduction to Energy Systems
ECE352	Computer Organization
ECE353	Systems Software
ECE360	Electronics

Energy & the Environment

APS510	Technologies and Organizations in Global Energy Systems
CHE308	Chemical Processes for Energy Generation and Storage
CIV300	Terrestrial Energy Systems
CIV301	Design of Hydro and Wind Electric Plants
CIV440	Environmental Impact and Risk Assessment
ECE359	Energy Conversion
MIE303	Mechanical and Thermal Energy Conversion Processes
MIE315	Design for the Environment
MIE515	Alternative Energy Systems

Infrastructure

CIV352	Structural Design I
CIV357	Structural Design II
CIV359	Intelligent Transportation Systems
CIV460	Engineering Project Finance and Management
CIV516	Public Transit Operations and Planning
CIV531	Transport Planning

Manufacturing

AER525	Robotics
CHE561	Risk Based Safety Management
MIE221	Manufacturing Engineering
MIE422	Automated Manufacturing
MIE440	Mechanical Design: Theory and Methodology
MIE469	Reliability and Maintainability Engineering
MIE540	Product Design

Mining

CME321	Geotechnical Engineering I
MIN401	Mineral Reserve and Mineral Resource Estimation
MIN430	Mining Environmental Management

Course Descriptions for technical electives from outside the Faculty:

APM466 **Mathematical Theory of Finance**

Introduction to the basic mathematical techniques in pricing theory and risk management: stochastic calculus, single-period finance, financial derivatives (tree-approximation and Black-Scholes model for equity derivatives, American derivatives, numerical methods, lattice models for interest-rate derivatives), value at risk, credit risk, portfolio theory.

STA410 Statistical Computation

Programming in an interactive statistical environment. Generating random variates and evaluating statistical methods by simulation. Algorithms for linear models, maximum likelihood estimation, and Bayesian inference. Statistical algorithms such as the Kalman filter and the EM algorithm. Graphical display of data.

STA447 Stochastic Processes

Discrete and continuous time processes with an emphasis on Markov, Gaussian and renewal processes. Martingales and further limit theorems. A variety of applications taken from some of the following areas are discussed in the context of stochastic modeling: Information Theory, Quantum Mechanics, Statistical Analyses of Stochastic Processes, Population Growth Models, Reliability, Queuing Models, Stochastic Calculus, Simulation (Monte Carlo Methods).

RSM412 Financial Trading Strategies

This course will apply finance theory in order to implement strategies for trading, investment, and managing risks, including model risk. The first part of the course emphasizes developing Excel applications linked to actual financial data to quantify risks and their impact on returns. We then apply what we have learned on the Rotman Interactive Trader platform for which our Excel applications will be linked to data from a simulated market, that is, data generated by the class participants. These interactive cases are analogous to using a flight simulator to learn to fly except in our case we are learning how to make effective financial decisions taking account of uncertainty about the future.

RSM430 Fixed Income Securities

Describes important fixed income securities and markets. The course emphasizes traditional bond and term structure concepts crucial to understand the securities traded in these markets. Students are required to work in the Rotman Financial Research & Trading Lab to solve the assigned problems using real time data.

RSM432 Risk Management for Financial Managers

This course examines the ways in which risks are quantified and managed by financial institutions. The principal risks considered include market risk, credit risk and operational risk. The course also covers the evolution of bank regulation and the regulatory limits on risk taking.